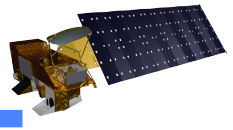
Aqua Summary

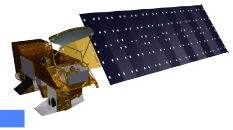
(as of March 31, 2020)



- **Spacecraft Bus** – Nominal Operations (Excellent Health)
  - All components remain on primary hardware.
  - 19 of 132 Solar Array Strings appear to have failed. See slide 2. Similar failures have occurred on Aura.
  - Significant power generation margin remains.
- **MODIS** – Nominal Operations (Excellent Health)
  - All voltages, currents, and temperatures are as expected.
  - All components remain on primary hardware except 10W Lamps used for calibration.
- **AIRS** – Nominal Operations (<10% of Channels degraded) – (Excellent Health)
  - All voltages, currents, and temperatures are as expected.
  - ~200 of 2378 channels are degraded due to radiation, however they are still useful.
  - Cooler-A Telemetry, frozen since a 3/28/2014 Anomaly, was restored during recovery activities performed on 9/27/2016.
- **AMSU-A** – Nominal Operations for 10 of 15 Channels (Fair Health)
  - All voltages, currents, and temperatures are as expected.
  - 3 of 15 channels have been removed from Level 2 processing. 2 channels (#1 & #2) are unavailable.
  - AMSU-A2 Anomaly on 9/24/2016 caused loss of Channels 1 and 2. The recovery attempts were unsuccessful. The instrument manufacturer recommends not switching to the A-side to attempt to recover AMSU-A2.
  - AMSU-A1 Anomaly on 6/21/2018 caused unexplained shift in Channel 14, but on 6/19/2019 the shift was unexpectedly reversed and the Channel recovered.
- **CERES-AFT (FM-3)** – Nominal Operations (Excellent Health)
  - All voltages, currents, and temperatures are as expected.
  - Cross-Track and Biaxial Modes are fully functioning.
  - All channels remain operational.
- **CERES-FORE (FM-4)** – Nominal Operations (Good Health)
  - All voltages, currents, and temperatures are as expected.
  - Cross-Track is Nominal. Biaxial Mode is Nominal when used. Successful test of Biaxial Mode conducted March 18, 2019.
  - The shortwave channel failed on March 30, 2005; the other two channels remain operational.
- **AMSR-E** – Off since March 2016
- **HSB** – Non-operational since February 2003 anomaly

Aqua Spacecraft Bus Status

(see Acronyms list at end)

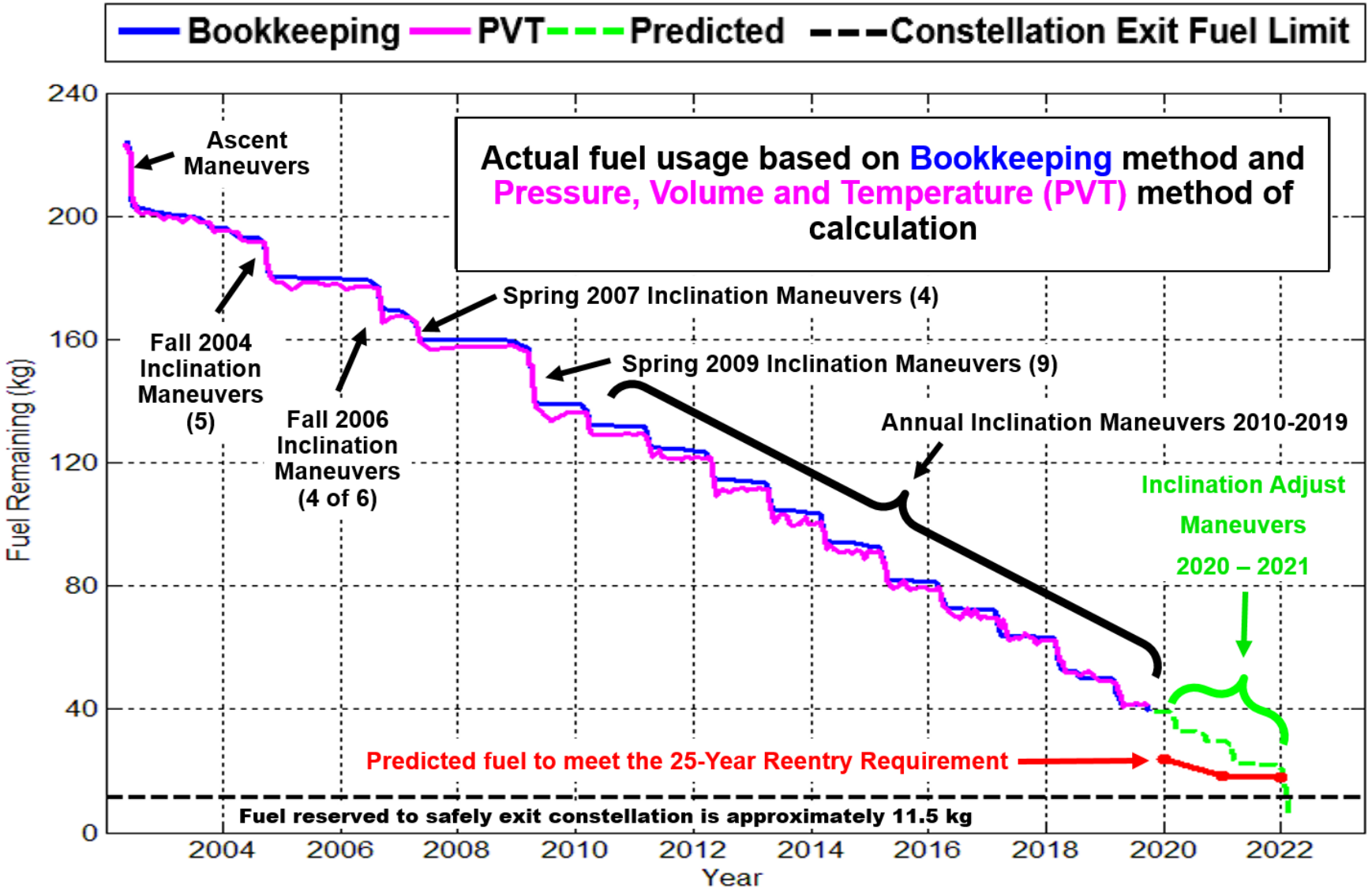


Subsystem	Component	Design	Current	Capability	Comments
Elect. Power	Solar Array	132 Strings	113 Strings	85.6%	19 out of 132 strings appeares to have failed.The latest failure occurred on 9/12/2019 and was confirmed during the 9/23/2019 EPS State of Health Test.
	Battery	24 Cells	24 Cells	Full	Anomalous performance on BMA-2 Cell 4 in September 2005, returned to nominal within weeks.
Thermal	TCLs	42	42	Full	Nominal Performance
OBC's	CTC	2	2	Full	2026 Flight Software Anomaly
	GNCC	2	2	Full	2026 Flight Software Anomaly
	PC	2	2	Full	2026 Flight Software Anomaly
	ISC	2	2	Full	2026 Flight Software Anomaly
Communications	X-Band String	2	2	Full	Nominal Performance
	S-Band String	2	2	Full	Nominal Performance
C&DH	USO-1	2	2	Full	Nominal Performance
	USO-2	2	2	Full	Nominal Performance
	FMU/SSR	136Gbits	136Gbits	Full	Nominal Performance
	C&T Bus	2	2	Full	Nominal Performance
	S/C Support Bus	2	2	Full	Nominal Performance
	PC Bus	2	2	Full	Nominal Performance
	GN&C Bus	2	2	Full	Nominal Performance
GN&C	CSSA	2	2	Full	Nominal Performance
	ESA	2	2	Full	Nominal Performance
	MTA	3	3	Full	Nominal Performance
	ODE	2	2	Full	Nominal Performance
	RWA	4	4	Full	Nominal Performance
	STA	2	2	Full	Monitoring a minor Star Tracker Residual Anomaly
	SADA	2	2	Full	Nominal Performance
	TAM	2	2	Full	Nominal Performance
	VDE	2	2	Full	Nominal Performance
	WDE	4	4	Full	Nominal Performance
Propulsion	DTM	4	4	Full	Nominal Performance

Aqua Spacecraft Bus is in Excellent Health.

Fuel Usage: Life of the mission

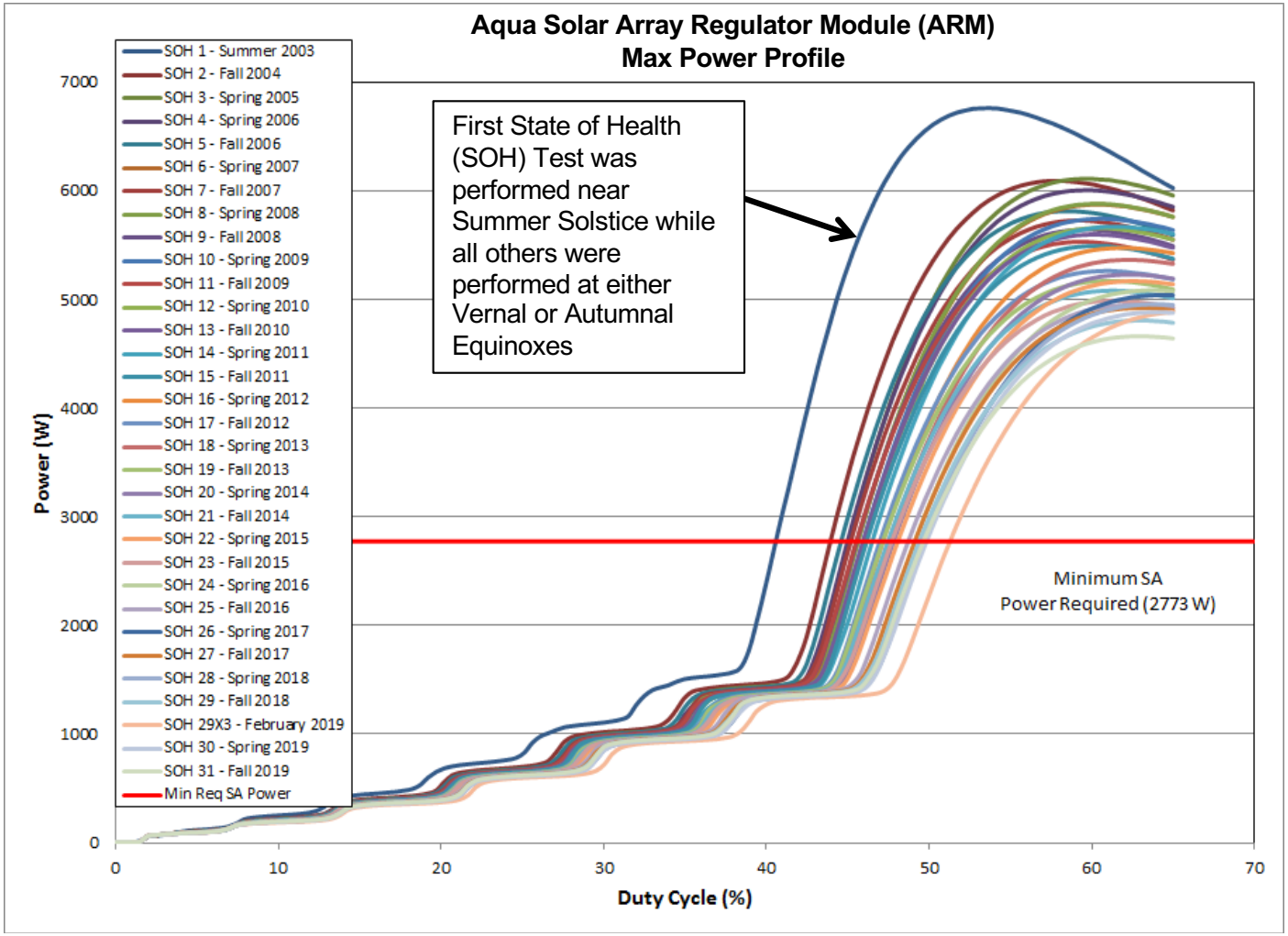
(November 2019)



Fuel usage continues to follow prediction.

Aqua Solar Array Power Margin Analysis

(Fall 2019)

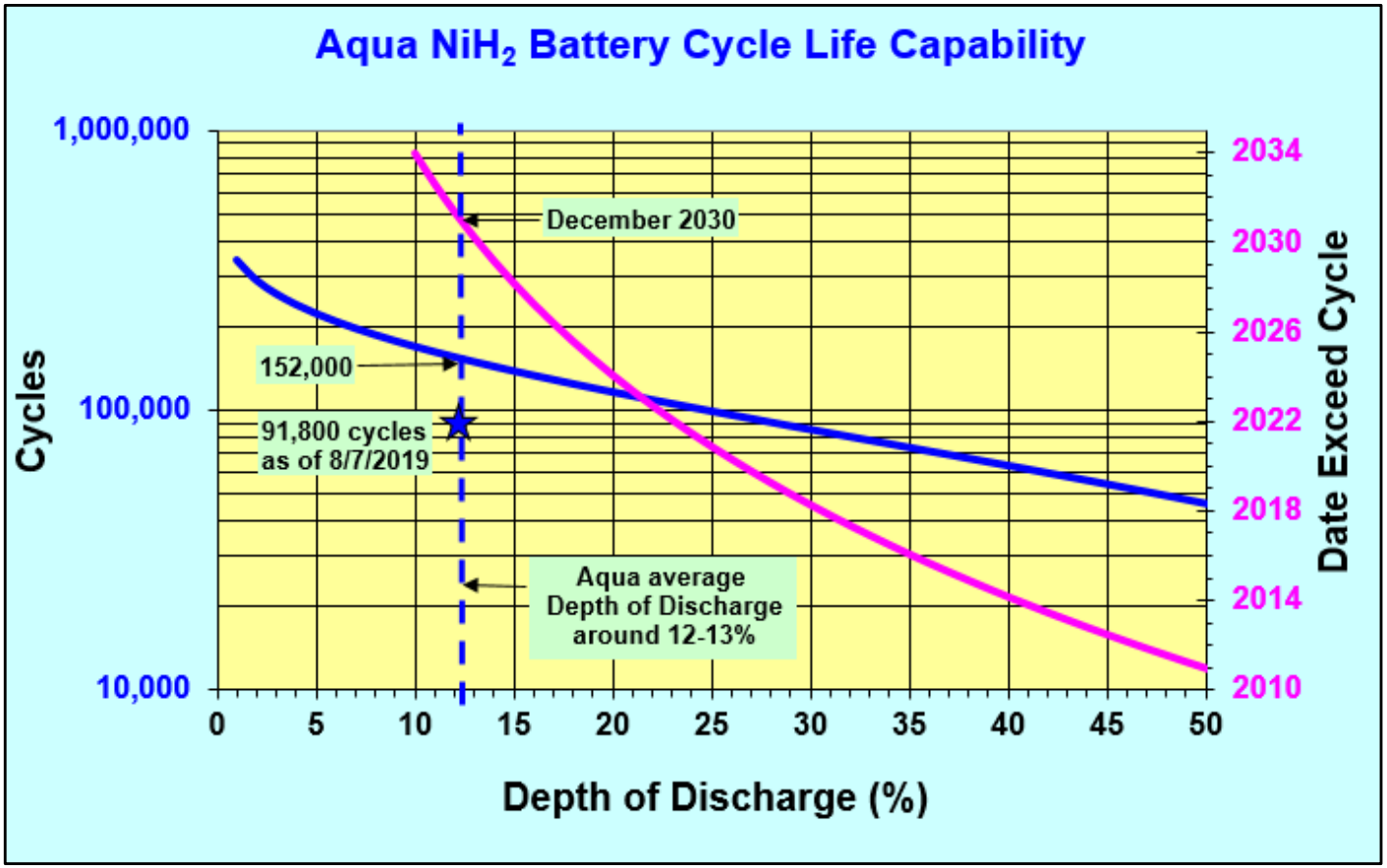


When comparing State Of Health (SOH) tests performed Near Equinoxes, Solar Array degradation has been as expected given the age of the spacecraft. The Solar Array is projected to be able to provide sufficient power at least until 2025, even with an anticipated exit from the A-Train in 2022.

Aqua Battery Life Projection

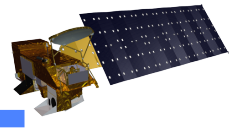
(August 2019)

- Extrapolating the Eagle-Picher NiH_2 Battery Cycle Life Capability data for the typical Aqua Depth-of-Discharge (12-13%) leads to a potential 152,000 cycles from launch that might be achievable with the cells.
- Aqua is projected to reach 152,000 cycles in December 2030.



Aqua Battery Life Capability projected through December 2030.

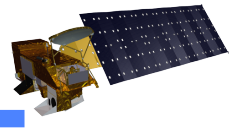
2019 Reliability Study



In Early 2019, the Safety & Mission Assurance Directorate (Code 300) Reliability and Risk Analysis Branch (Code 371) at NASA Goddard Space Flight Center updated reliability analysis based on current on-orbit performance, constraints and wear effects due to 16.5 years on-orbit for extended mission out to the end of 2027. There is a 92.9% probability Aqua Spacecraft (S/C) Bus will function past 2025. Year identified is end of year.

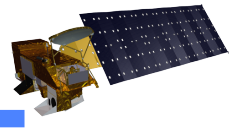
	2019	2020	2021	2022	2023	2024	2025	2026	2027
Spacecraft (S/C) Bus	0.990	0.979	0.969	0.959	0.948	0.938	0.929	0.919	0.909
S/C Bus + MODIS	0.971	0.942	0.915	0.888	0.862	0.836	0.812	0.788	0.765
S/C Bus + AIRS	0.979	0.958	0.937	0.917	0.897	0.878	0.859	0.841	0.823
S/C Bus + CERES	0.986	0.968	0.945	0.918	0.890	0.859	0.827	0.795	0.762
S/C Bus + MODIS & CERES	0.968	0.931	0.892	0.851	0.808	0.766	0.723	0.682	0.641
S/C Bus + MODIS & AIRS	0.960	0.922	0.885	0.849	0.815	0.783	0.751	0.721	0.692
S/C Bus + AIRS & CERES	0.976	0.946	0.914	0.879	0.842	0.804	0.766	0.727	0.689
S/C Bus + MODIS, AIRS & CERES	0.957	0.911	0.863	0.814	0.765	0.717	0.669	0.624	0.580

Aqua MODIS Instrument Facts



- 36-band cross-track scanning radiometer, also on Terra
- Visible to thermal infrared measurements at 0.4-14.5 μm
- Spatial resolution: 250 m to 1 km
- Swath width: 2330 km
- Global coverage every 1-2 days
- Heritage: AVHRR, HIRS, Landsat TM, Coastal Zone Color Scanner (CZCS), SeaWiFS
- Prime Contractor: Raytheon Santa Barbara Remote Sensing (SBRS)
- Responsible Center: NASA Goddard Space Flight Center

Aqua MODIS Instrument Status



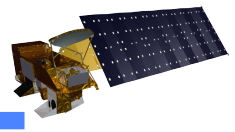
- All voltages, currents, and temperatures are as expected.
- There are no disturbing trends in any engineering parameter.
- Aqua MODIS continues to operate on prime equipment.
  - Full redundancy exists except for 10 W Lamps used for calibration
    - Lamps #2, #3 and #4 failed prematurely.
    - Able to use remaining lamp for calibration purpose
    - If the last 10 Watt Lamp (Lamp #1) would also fail, the impact to MODIS science data would be minor. The MODIS scientists have nearly phased out data corrections based on calibration, as the MODIS data have been very stable.

Life Limiting Items	Designed	5/4/2002	4/3/2020
SRCA 10 W Lamp #1 (Hours of use)	500	200.2	376.3
SRCA 10 W Lamp #2 [1] (Hours of use)	500	175.7	188.1
SRCA 10 W Lamp #3 [1] (Hours of use)	500	178.5	205.7
SRCA 10 W Lamp #4 [1] (Hours of use)	500	57.7	135.0
SRCA 1 W Lamp #1 (Hours of use)	5000	499.5	531.8
SRCA 1 W Lamp #2 (Hours of use)	5000	269.8	307.1
Solar Diffuser Door Movements (Open or Close)	3022	1630	3574 [2]
Nadir Aperture Door Movements (Open or Close)	1316	1046	1053
Space View Door Movements (Open or Close)	1316	624	632

1. Spectroradiometric Calibration Assembly (SRCA) 10 W Lamp #2, Lamp #3 and Lamp #4 are no longer functional.
2. Solar Diffuser Door Movements have exceeded design. Use of Door has been reduced from once per week to once every 6 weeks. Use of Screen was reduced from once per week to once every three weeks. Modified calibration is possible if door fails.

Aqua MODIS is in Excellent Health.

MODIS Lunar Calibration



- MODIS Lunar Calibration is performed ~4 days before full moon.
  - Performed when spacecraft roll is less than 20^{o}
  - Executed ~10 times annually

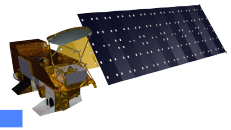
- MODIS formatter rate is changed from night rate to day rate during the calibration period.
  - Done every Spacecraft-Day/Night
  - No additional risk to instrument

- Modify sector rotation
  - Done in software only
  - MODIS scan mirror rotation at constant speed regardless of MODIS Roll or nominal science
  - No additional risk to instrument

There are no door or screen closing or mechanical changes to MODIS during MODIS Roll Maneuvers, therefore there is no risk specific to MODIS instrument.

The only added risk regarding MODIS Roll Maneuvers is with the spacecraft being off-pointing during the calibration.

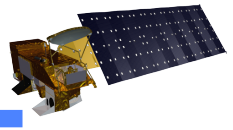
AIRS Instrument Facts



AIRS Instrument Facts

- 2382-channel grating spectrometer unique to Aqua
- Visible/near-IR and IR measurements at 0.41-0.94 μm (4 channels) and 3.7-15.4 μm (2378 channels)
- Spatial resolution: 13.5 km (IR) and 2.3 km (visible) at nadir
- Swath width: 1650 km
- Global coverage every 1-2 days
- Heritage: Advanced Moisture and Temperature Sounder (AMTS), High Resolution Infrared Sounder (HIRS)
- Prime Contractor: BAE Systems
- Responsible Center: NASA Jet Propulsion Laboratory (JPL)

AIRS Instrument Status



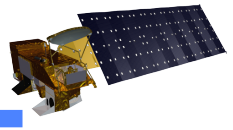
All voltages, currents, and temperatures are as expected.

- Includes scanner currents, cooler drive levels and heater currents
- On September 25, 2016, Cooler-A experienced a shut down anomaly. Anomaly recovery occurred two days later and also cleared a condition that had disabled Cooler-A telemetry since an earlier Cooler-A anomaly in March 2014.

- There are no disturbing trends in any engineering parameter.
- Design has considerable spectral redundancy and channels have a pair of detectors whose outputs are combined onboard allowing for correction if only one detector is degraded.
- Approximately 200 of 2378 infrared channels are degraded, primarily due to radiation.
  - Symptoms: increase in Gaussian and non-Gaussian noise
  - These channels are degraded; however, they are still useful for climate studies where averages over many data samples are taken.
  - Uploaded gain change to correct degraded channels for non-Gaussian Noise. Usually a degraded channel has had only one of the two detectors affected.
    - Corrected 106 Channels on January 21, 2012
    - Corrected 10 Channels on June 10, 2013
    - Corrected 91 Channels on March 23, 2015
    - Corrected 46 Channels on October 3, 2019
    - Additional channels can be corrected depending on science team request
  - Increased solar activity may increase degradation rate since the channels are susceptible to radiation.

AIRS is in Excellent Health.

AMSU Instrument Facts

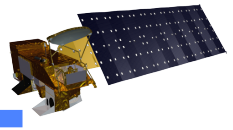


AMSU Instrument Facts

- 15-channel microwave sounder, also on NOAA satellites since 1998
- Microwave measurements at 23-90 GHz (0.3-1.3 cm)
- Spatial resolution: 40.5 km at nadir
- Swath width: 1690 km
- Global coverage every 1-2 days
- Heritage: Microwave Sounding Unit (MSU)
- Prime Contractor: Northrop Grumman Aerospace Systems (NGAS)
- Responsible Center: NASA Goddard Space Flight Center

Note: “AMSU” here is the same instrument as the
“AMSU-A” mentioned on other slides in this package.

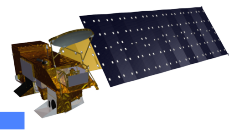
AMSU-A Instrument Status



- All voltages, currents, and temperatures are as expected
- There are no disturbing trends in any engineering parameter
- Designed for 3 years (now well beyond design life)
- 10 of 15 Channels continue to perform well, and of those, 8 show no signs of degradation
- 5 of 15 Channels have degraded and are no longer used for science
  - 5/4/2002: Channel 7 has not met noise specifications since launch (suspect launch related damage) and has never been used
  - 3/5/2008: Channel 4 data removed from level 2 processing; Declared non-operational in November 2007
  - 4/13/2012: Channel 5 data removed from level 2 processing; Declared non-operational in April 2012
  - 9/24/2016: Channels 1 and 2 (AMSU-A2) suffered a power anomaly; efforts to restore power to AMSU-A2 were unsuccessful, and since the exact cause of the anomaly was unknown, the instrument manufacturer recommended not switching to the A-side to attempt recovery; on 11/29/2016 the Anomaly Recovery Team (ART) recommended no further commanding, and since the Anomaly Closeout Review at JPL on 1/31/2017, the Anomaly has been considered Closed
- 1 Channel (# 14) underwent an unexpected anomaly on 6/21/2018, but, just as unexpectedly, recovered on 6/19/2019.
- 1 Channel (# 6) is slowly degrading but has many years of useful performance remaining based on current degradation rate
- The scanner and 9 channels appear capable of lasting several more years

AMSU-A is in Fair Health.

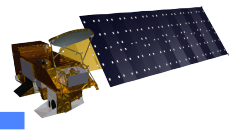
AMSR-E Instrument Facts



AMSR-E Instrument Facts

- *Instrument type:* Passive microwave radiometer, twelve channels, six frequencies, dual polarization (vertical and horizontal); offset parabolic reflector, 1.6 m in diameter and drum designed to rotate at 40 rpm; six feedhorns to cover six bands in the range 6.9–89 GHz with 0.3–1.1 K radiometric sensitivity.
- *Channels:* 12
- *Spectral Range:* 0.34–4.35 cm
- *Frequency Range:* 6.9–89.0 GHz
- *Swath Width:* 1445 km
- *Spatial Resolution:* 6 km × 4 km (89.0 GHz), 14 km × 8 km (36.5 GHz), 32 km × 18 km (23.8 GHz), 27 km × 16 km (18.7 GHz), 51 km × 29 km (10.65 GHz), 74 km × 43 km (6.925 GHz)
- *View: Forward-looking conical scan*
- *Incidence Angle: 55°*
- *Instrument Field of View (IFOV) at Nadir: Ranges from 74 km × 43 km for 6.9 GHz to 6 km × 4 km for 89.0 GHz*
- *Sampling Interval: 10 km for 6–36 GHz channels*
- *Calibration: External cold load reflector and a warm load for calibration*
- *Accuracy: 1 K or better*
- Global coverage every 1 to 2 days
- Heritage: SMMR (on Nimbus-7 and Seasat), SSM/I (on DMSP), AMSR (on ADEOS II)
- Prime Contractor: Mitsubishi Electric Company (MELCO)
- Responsible Center: Japan Aerospace Exploration Agency (JAXA)

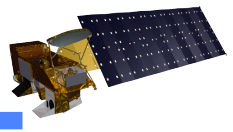
AMSR-E Instrument Status



- In October 2011, AMSR-E was no longer able to maintain 40 rpm rotation and was spun down to 0 rpm.
- The cause of anomaly is likely to be a bearing and/or lubrication issue. The AMSR-E instrument far exceeded 3 year design life as the instrument performed nominally for 9+ years although signs of bearing/lubrication wear were obvious.
- To facilitate calibration with the AMSR2 instrument on Japan's Shizuku satellite, the instrument was spun back up to 2 rpm on December 4, 2012 after addressing the risk of potential AMSR-E momentum imbalance that could trip Aqua into safe-hold.
- Antenna was spun down from 2 rpm to 0 rpm due to stall indications observed in telemetry on December 4, 2015. Since AMSR-E spin-down was already planned for December 8, 2015, no recovery actions were conducted.
- Configured the instrument to Survival Mode on December 8, 2015, concluding AMSR-E Operations.

AMSR-E was turned off on March 2, 2016.
No plans to turn AMSR-E back on.

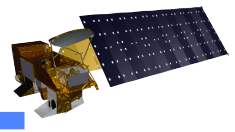
CERES Instrument Facts



CERES Instrument Facts

- Quantity on Aqua: 2 (CERES-AFT and CERES-FORE)
- Operational On-Orbit: 2-Aqua, 2-Terra, 1-Suomi National Polar-Orbiting Partnership (SNPP), 1-NOAA 20 (Formally known as the Joint Polar Satellite System (JPSS-1) satellite)
- Channels: 3 radiometers per instrument
- Spectral Range: One channel each measuring total radiance (0.3 to >100 μm), shortwave radiance (0.3-5 μm), and the radiance in the atmospheric window at 8-12 μm
- Spatial Resolution: 20 km at nadir
- Swath width: Limb to limb of the Earth view
- Field of View: ±78^{o} cross-track, 360^{o} azimuth
- Instrument IFOV: 14 mrad
- Global coverage Daily
- Heritage: Earth Radiation Budget Satellite (ERBE)
- Prime Contractor: Northrop Grumman Aerospace Systems (NGAS)
- Responsible Center: NASA Langley Research Center

CERES Instrument Status



CERES-AFT (FM-3)

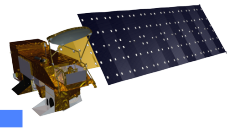
- All voltages, currents, and temperatures are as expected.
- There are no disturbing trends in any engineering parameter.
  - Bi-axial Mode – Nominal, when used
  - Cross-Track Mode – Nominal

CERES-FORE (FM-4)

- All voltages, currents, and temperatures are as expected.
- There are no disturbing trends in any engineering parameter.
  - Bi-axial Mode – Nominal, when used
    - CERES FM-4 sensor stopped collecting valid Shortwave channel radiometric measurements on March 30, 2005
    - Failure of the Shortwave channel on one CERES did not prevent the accomplishment of any of the mission's scientific objectives
    - Successful test of Biaxial Mode conducted March 18, 2019.
  - Cross-Track Mode – Nominal

CERES-AFT is in Excellent Health.
CERES-FORE is in Good Health.

HSB Instrument Facts

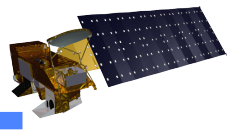


HSB Instrument Facts

- Heritage: AMSU-B
- Instrument Type: Microwave radiometer
- Aperture: 18.8 cm
- Channels: 4
- Spectral Range: 150–190 GHz
- Swath Width: 1650 km
- Coverage: Global every 1 to 2 days
- Spatial Resolution: 13.5 km at nadir
- FOV: ± 49.5° cross-track from nadir
- Instrument IFOV: 1.1° (13.5 km at nadir)
- Pointing Accuracy: 0.1°
- Scan Period: 2.667 s
- Scan Sampling: 90 × 1.1°, in 1.71 s
- Sensitivity: 0.3–0.68 K, depending on spectral region
- Prime Contractor: Astrium (formerly Matra Marconi Space, United Kingdom)
- Provider: Instituto Nacional de Pesquisas Espaciais (INPE, the Brazilian Institute for Space Research)

HSB has been non-operational since February 2003 due to an apparent electrical component failure in the scan drive system.

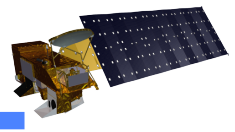
Data Latency



- EOS Data and Operations System (EDOS): Average 1 hours, 55 minutes end-to-end from February 21, 2020 – March 20, 2020. Latency refers to the amount of time between the start time of the observation and the time that EDOS Level 0 products are delivered to the data processing facilities (DAAC, SIPS, MODAPS, etc.); 30 minutes from Loss Of Signal (LOS) at the ground station until delivery to the data processing facilities.

- Land and Atmosphere Near-real-time Capability for EOS (LANCE) latency: Average time based on the following calculation: from the mid-time of each granule to the time that Level 1, 2, and 3 products are available at the ftp website. *Note:* Each instrument granule has a specific duration, e.g., MODIS granule period is 5 minutes. For the period March 1, 2020 – March 28, 2020 the average latency was 107 minutes for AIRS and 171 minutes for MODIS.

Data Access



- Realtime Direct Broadcast to over 200 stations world-wide
- Processed data are available at the following centers*:
  - The Goddard Earth Sciences Data and Information Services Center for the AIRS and AMSU data (disc.gsfc.nasa.gov/AIRS)
  - The National Snow and Ice Data Center for AMSR-E data and MODIS snow and ice data (nsidc.org/data/amsre)
  - The Langley Research Center (LaRC) Distributed Active Archive Center (DAAC) for CERES data (eosweb.larc.nasa.gov)
  - The Land Processes DAAC for MODIS land data (lpdaac.usgs.gov)
  - The Level 1 and Atmosphere Archive and Distributed System for MODIS atmosphere data (ladsweb.nascom.nasa.gov)
  - The Ocean Biology Processing Group site for MODIS ocean color data (oceancolor.gsfc.nasa.gov)
  - The Physical Oceanography DAAC for MODIS sea surface temperatures (http://podaac.jpl.nasa.gov/datasetlist?search=AQUA)
  - The Land and Atmosphere Near real-time Capability for EOS (LANCE) (https://earthdata.nasa.gov/data/near-real-time-data/about-lance)

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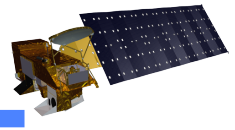

AIRS	Atmospheric Infrared Sounder
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AMSU	Advanced Microwave Sounding Unit
AMTS	Advanced Moisture and Temperature Sounder
ARM	Array Regulator Module
AVHRR	Advanced Very High Resolution Radiometer
CERES	Clouds and the Earth's Radiant Energy System
CSSA	Coarse Sun Sensor Assembly
CZCS	Coastal Zone Color Scanner
C&DH	Command & Data Handling
C&T	Command & Telemetry
DAAC	Distributed Active Archive Center
Delta-i	Inclination Maneuver
DMSP	Defense Meteorological Satellite Program
DTM	Dual Thruster Module
EDOS	EOS Data and Operations System
EOS	Earth Observing System
ERBE	Earth Radiation Budget Experiment
ESA	Earth Sensor Assembly
ESDIS	Earth Science Data and Information System
ESMO	Earth Science Mission Operation
FM	Flight Model
FMU	Formatter-Multiplexer Unit
FOV	Field of View
GN&C	Guidance, Navigation & Control
HIRS	High Resolution Infrared Sounder
HSB	Humidity Sounder for Brazil
IFOV	Instrument Field of View
INPE	Instituto Nacional de Pesquisas Espaciais
IR	Infrared
ISC	Instrument Support Controller
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
LANCE	Land and Atmosphere Near-real-time Capability for EOS

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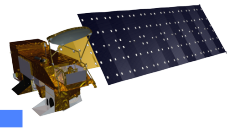

LOS	Loss of signal
MELCO	Mitsubishi Electric Company
MODAPS	MODIS Adaptive Processing System
MODIS	Moderate Resolution Imaging Spectroradiometer
MSU	Microwave Sounding Unit
MTA	Magnetic Torque Assembly
NASA	National Aeronautics and Space Administration
NGAS	Northrop Grumman Aerospace Systems
NOAA	National Oceanic and Atmospheric Administration
OBC	On Board Computer
ODE	Orientation Drive Electronics
PC	Power Controller
rpm	revolutions per minute
RWA	Reaction Wheel Assembly
SA	Solar array
SADA	Solar Array Drive Assembly
SBRS	Santa Barbara Remote Sensing
S/C	Spacecraft
SeaWiFS	Sea-viewing Wide-Field-of-View Sensor
SIPS	Science Investigator-led Processing System
SMMR	Scanning Multichannel Microwave Radiometer
SNPP	Suomi National Polar-Orbiting Partnership
SOH	State of Health
SRCA	Spectroradiometric Calibration Assembly
SSMI	Special Sensor Microwave Imager
SSR	Solid State Recorder
STA	Star Tracker Assembly
TM	Thematic Mapper
TAM	Three-Axis Magnetometer
USO	Ultra Stable Oscillators
VDE	Valve Drive Electronics
WDE	Wheel Drive Electronics